

Greater Green River Basin Production Improvement Project, Rock Island 4-H, Table Rock Field, Frontier Formation

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Abstract

The objective of this effort is to reduce the technical risks and the economic uncertainty standing in the way of increased efficient industry development of the low-permeability (tight) gas resources of the Greater Green River Basin (GGRB) of Wyoming. The overall goal is to encourage development and utilization of the GGRB tight gas resources by industry. Two of the most prolific tight gas reservoirs in the Green River Basin, the Frontier and the Mesaverde, have been extensively developed in the Moxa Arch and Wamsutter Arch areas, respectively, using vertical wells and hydraulic fracture treatments. The deeper, overpressured areas of the basin have been much less developed due to uneconomic production rates. Yet, the Scotia Group 1993 study identified as much as 200 Tcf of deep Frontier and 50 Tcf of deep Mesaverde gas resource potential. Lower than normal reservoir permeabilities/porosities and the lack of extensive natural fractures are attributed for the low productivities in previous drilled deep wells. The subject project is intended to reduce these technical risks by testing more effective hydraulic fracturing techniques in a vertical wellbore or to intersect significantly more natural fractures in a horizontal or deviated wellbore. The approach to the project consisted of three phases: Phase I Site Characterization, Phase II Vertical Characterization Well, and Phase III Horizontal Well. Phases I and II resulted in the drilling of the Stratos #1 well (S24-T22N-R107W) through the Second Frontier to a total depth of 16,250 ft. Reservoir characterization and production testing of the Frontier formation determined this location was not favorable for attempting an advanced hydraulic fracture treatment nor for attempting a horizontal lateral. Further site characterization work identified the preferred location and wellbore azimuth for attempting a horizontal lateral to intersect substantial natural fractures in the overpressured Frontier formation on the eastern flank of the Rock Springs Uplift. The blanket marine and lenticular fluvial reservoirs characteristic of the Second Frontier represent prime candidates for a demonstration project that would compare production improvements by drilling, completing and testing of vertical and horizontal, directionally-drilled, wells. Developing techniques to more effectively and economically improve exploitation efficiencies in the Second Frontier has potentially high rewards because this previously unattainable gas resource in the deep Frontier is so large.

The horizontal well is located on the north plunge of Table Rock Field (S4-T19N-R97W) in Sweetwater County, southwestern Wyoming. The UPR Rock Island 4-H well (RI-4H) is offset to a vertical well completion, the Government Union #4 (GU #4) located in S8-T19N-R97W,

about 1.5 miles southwest of the RI-4H location. GU #4 is currently producing at 5 mmcf/d gas rate from the marine sand (Second Bench) of the Second Frontier formation. Core and log information and production tests from the Government Union #4 well, combined with structural data derived from approximately 1000 square miles of 3-D seismic data were major factors used in the site selection for the RI-4H horizontal well. The path of the horizontal lateral was chosen to be in a direction north 35° east to intersect two sets of natural fractures orientations: a major east-west set and a minor north-south set.

The RI-4H well was spudded on October 14, 1998 and a 14-3/4" vertical borehole was drilled to a depth of 9,517' and set with 11-3/4" casing. Further drilling of a 10-5/8" vertical borehole was done to a depth of 14,440', the kick-off-point (KOP) for directional drilling. From KOP, a 10-5/8" medium radius borehole was drilled at an initial build-up-rate (BUR) of 14° per 100 ft decreasing to a BUR of 4°/100' in the lower curve. At a depth of 15,025' the borehole deviation was 88° and a 7-5/8" liner was cemented into the curve. Using UPR geosteering patented technology, the 6-1/2" horizontal lateral was directionally drilled to stay inside a 20' vertical window within the marine sand of the Second Frontier formation. Since no vertical pilot hole was drilled, offset well logs from the Table Rock #44 well, over 2 miles from the RI-4H, was used for correlation. Once the lateral penetrated the fluvial zone and into the marine zone, the well remained in the marine target zone until it faulted back to the fluvial near the end of the lateral. Total length of the lateral was 1,750' to a final well TD of 16,784' MD (14,953' TVD). This is perhaps a world record depth for a tight gas sandstone horizontal well. Three horizontal cores totaling 77 ft were taken between 15,424'-15,951' MD (14,889'-14,928' TVD), considered to be the deepest horizontal sandstone cores ever taken. The well was completed open-hole using 4" slotted liner and equipped with 2-7/8" tubing and packer. The well was flow tested up to a 12 mmcf/d rate, one of the highest gas flow capacities ever encountered in the tight-gas province of the Cretaceous Frontier formation in Wyoming.

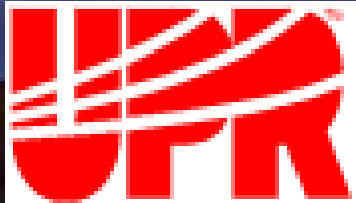
The RI-4H encountered reservoir sand that is dominantly massive to hummocky cross-stratified, very-fine grained, nearshore marine (lower shoreface) sandstone, with about 10% porosity, 25 microdarcies permeability, and is highly fractured. Fractures in the vertical GU #4 core and the horizontal RI-4H core indicate a shear displacement with a dominant strike orientation ranging from 80 to 110 degrees. The fractures are open to partially filled with calcite, quartz, kaolinite and bitumen. Open fractures which strike east-west occur along the entire length of the well, as observed in the core and microresistivity image log data.

Since May 13, 1999 the RI-4H has been flowed to a gas sales pipeline at an average rate of 14 mmcf/d for its first full month of production. The success of the UPR Rock Island 4-H well is anticipated to spark a renewed drilling effort by industry in the deep Frontier Greater Green River Basin. Horizontal drilling is attractive because it allows large well spacings, making per well recoveries larger and greatly reducing environmental impact. Union Pacific Resources is initiating plans to organize operators and leaseholders to form a Federal Unit to efficiently develop this play. Further testing of advanced drilling and stimulation techniques will occur as industry works to optimize technological and economic solutions. This project underscores the value of government and industry research partnerships aimed at solving challenging problems.

Contract No.DE-AC21-95MC31063

Greater Green River Basin

Production Improvement Project



- **Lee Krystinik, UPR Geologist and Principal Investigator**
- **Frank Lim, UPR Engineer and Contract Administrator**

- **Gary Covatch, FETC Engineer**
- **Tom Mroz, FETC Geologist**



Rock Island 4-H

Table Rock Field, Frontier Formation

PROJECT OBJECTIVE (TARGET)

*** REDUCE TECHNICAL RISKS and
ECONOMIC UNCERTAINTY to
ENCOURAGE DEVELOPMENT of the
200 TCF GAS RESOURCE POTENTIAL**

*** LOCATED in the DEEP OVERPRESSURED,
FRONTIER FORMATION in the GREEN
RIVER BASIN of SOUTHWEST WYOMING**

METHOD (APPROACH) TO PROJECT

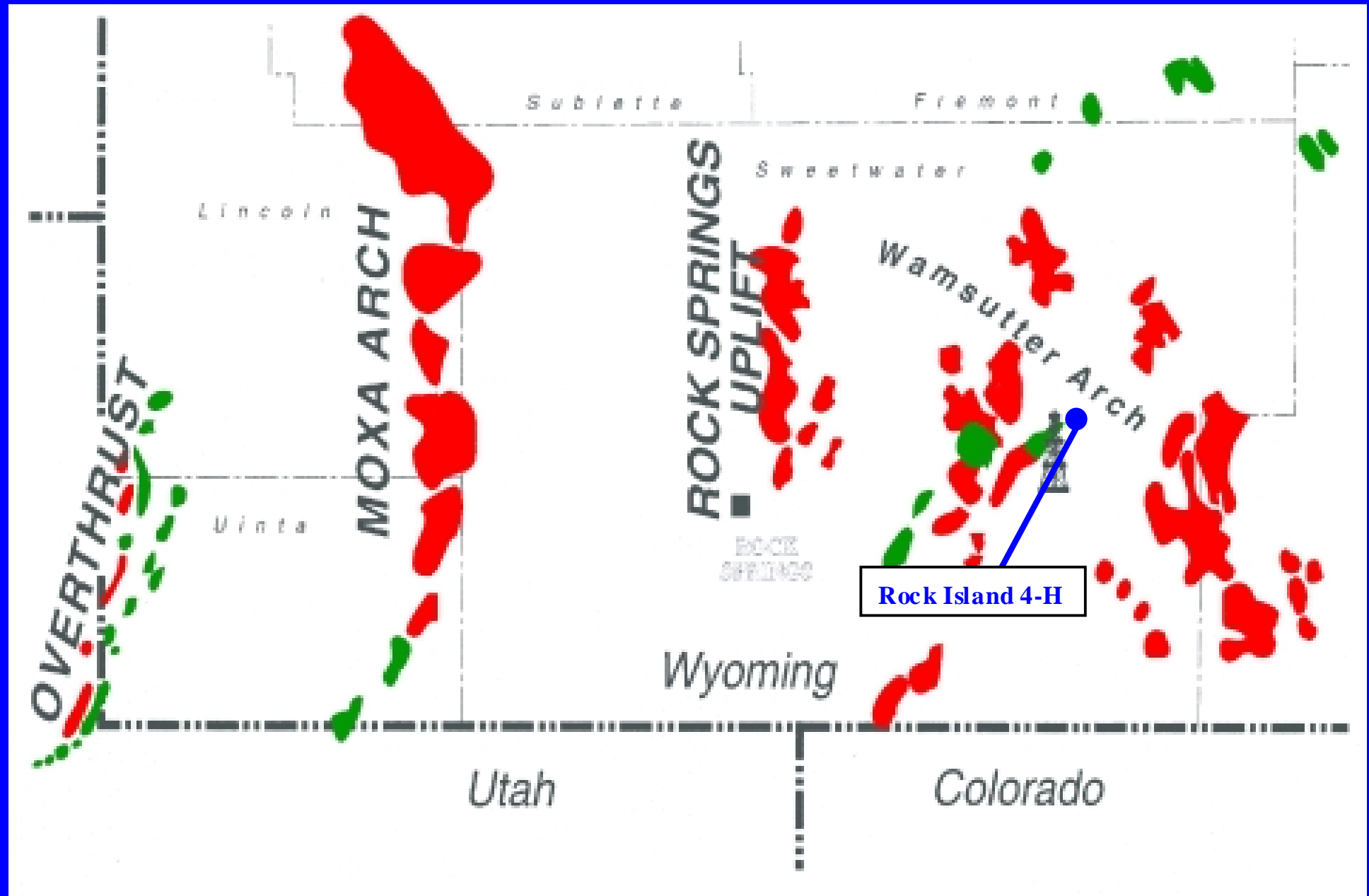
*** LOCATE and CHARACTERIZE “SWEET SPOTS” with
GOOD NATURAL FRACTURES and MATRIX PROPERTIES**

*** USE a VARIETY of METHODS including VERTICAL and
HORIZONTAL WELLS with HYDRAULIC FRACTURE
STIMULATION (as needed) while REDUCING COSTS**

*** USE CORING, LOGGING, and PRODUCTION TESTING
to DEMONSTRATE RESULTS of FIELD TESTING**

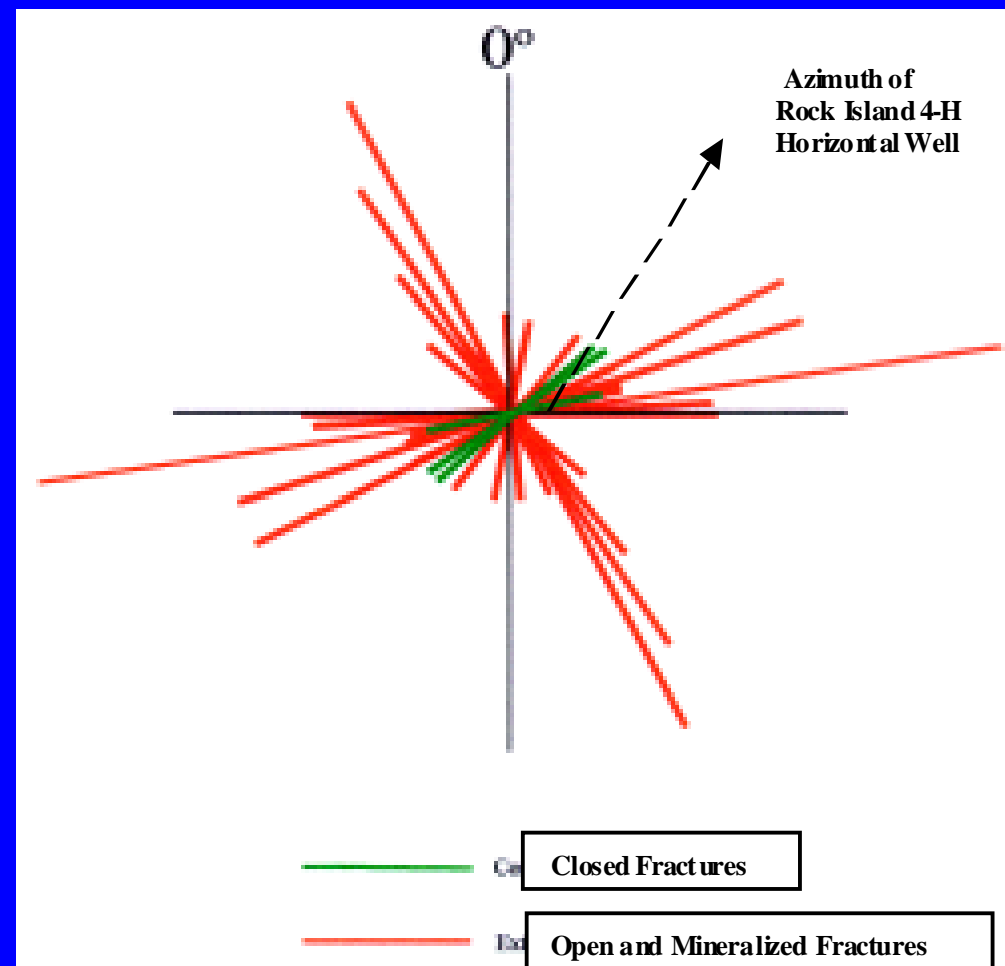
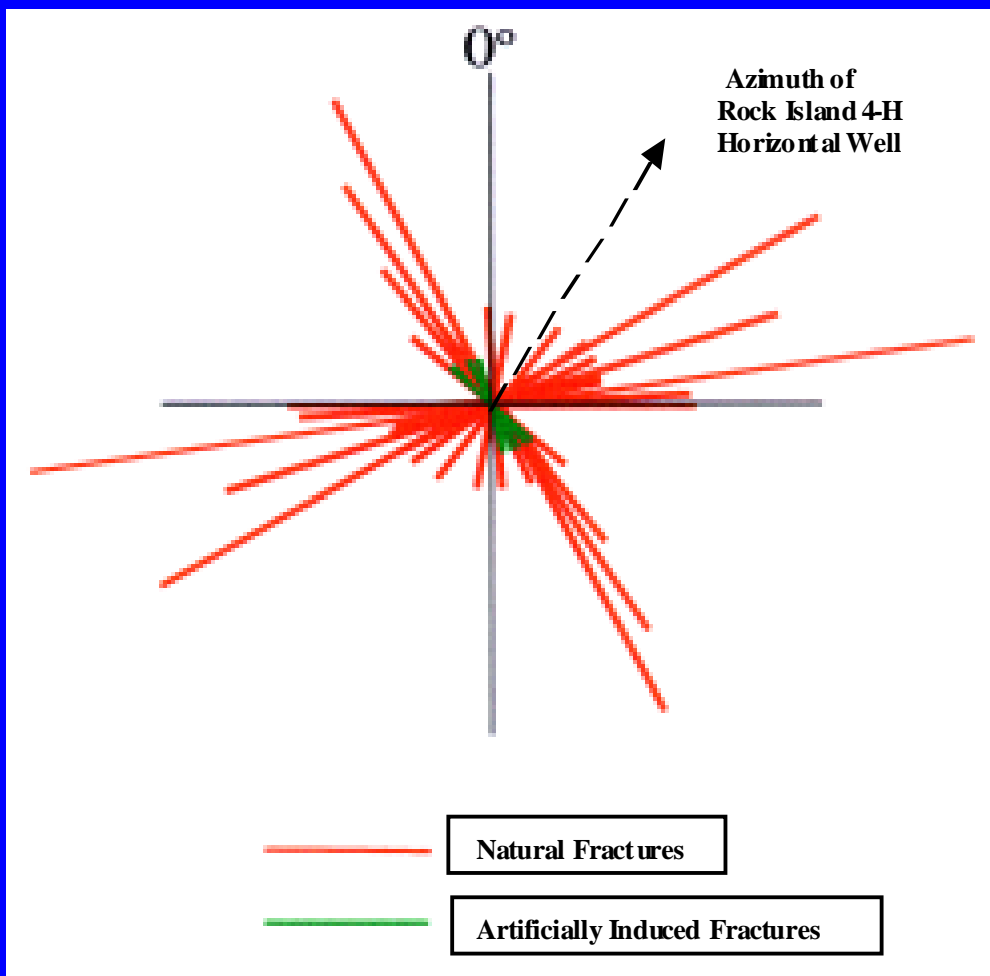
ROCK ISLAND 4-H WELL LOCATION (SW S4-T19N-R97W)

Major Oil and Gas Fields of SW Wyoming



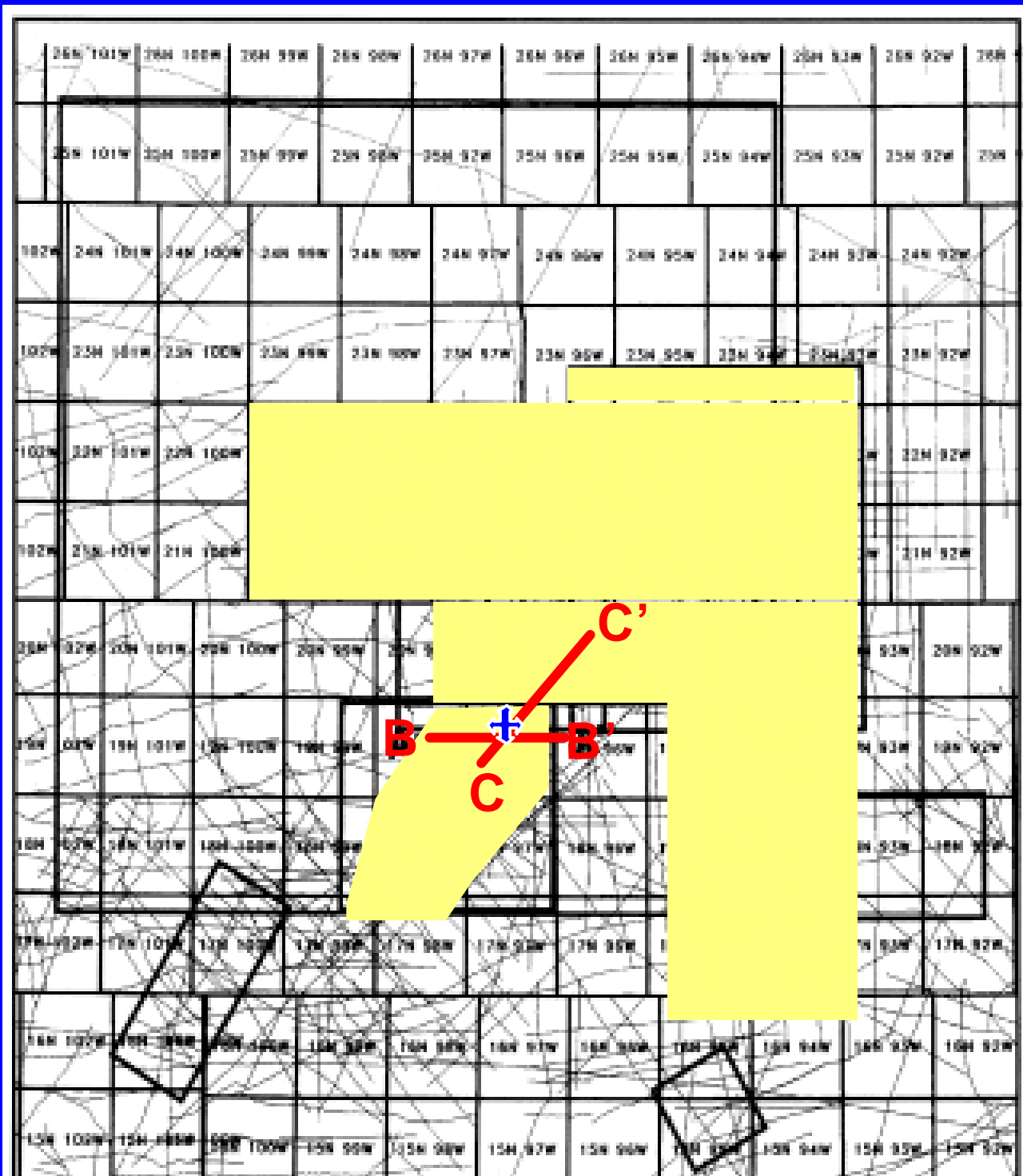
HORIZONTAL WELL PATH AZIMUTH NEEDED TO INTERSECT NATURAL FRACTURES

Fracture Orientations Govt. Union #4, Vertical Core

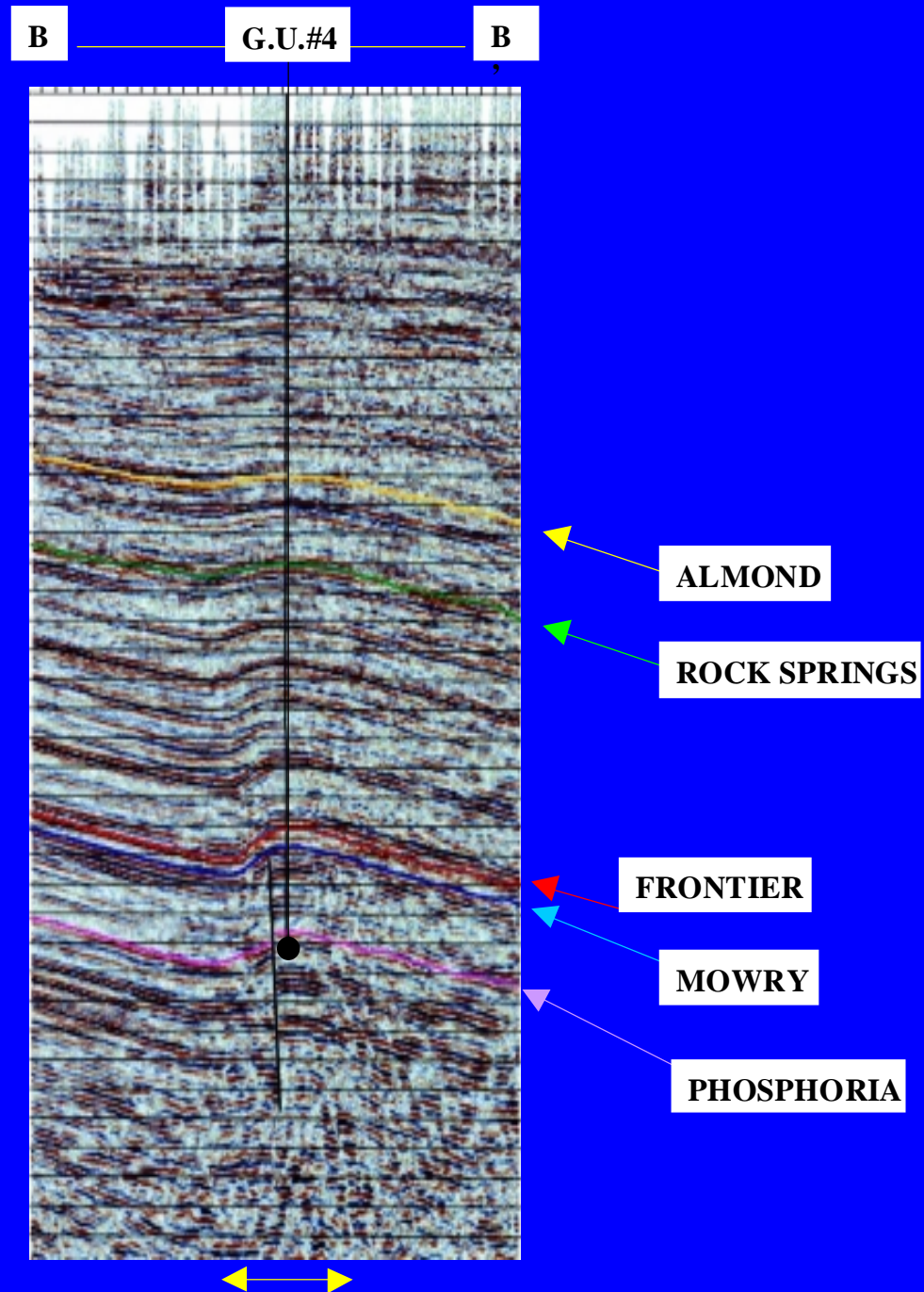


Seismic Site Selection of Rock Island 4-H Well Location

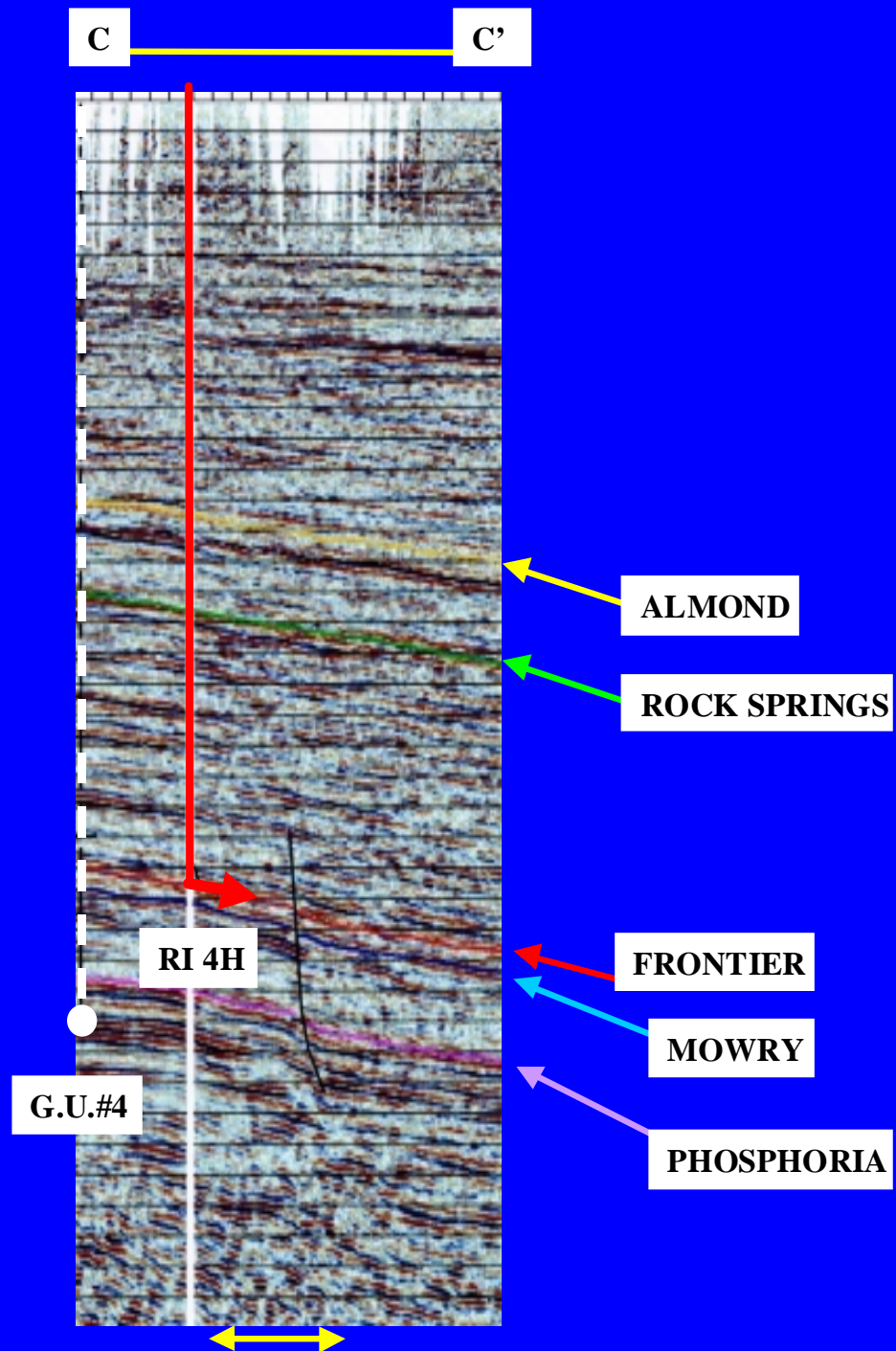
3-D Seismic Coverage of the Rock Island 4-H Project Area



Structural Dip Seismic Section Through the Govt. Union #4 Well



Well Path Seismic for the Rock Island 4-H Well



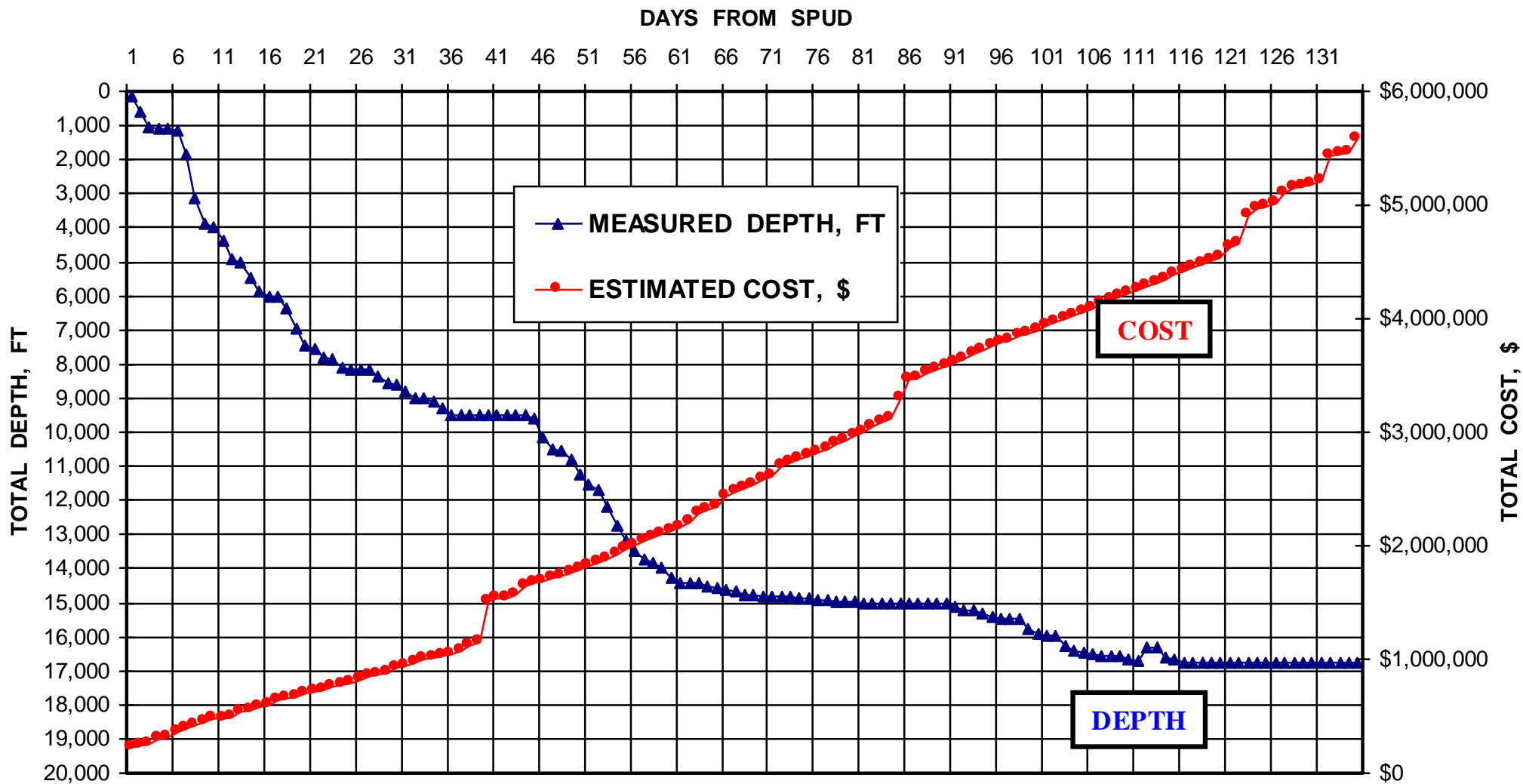
Rock Island 4-H, Parker #235 Drilling Rig



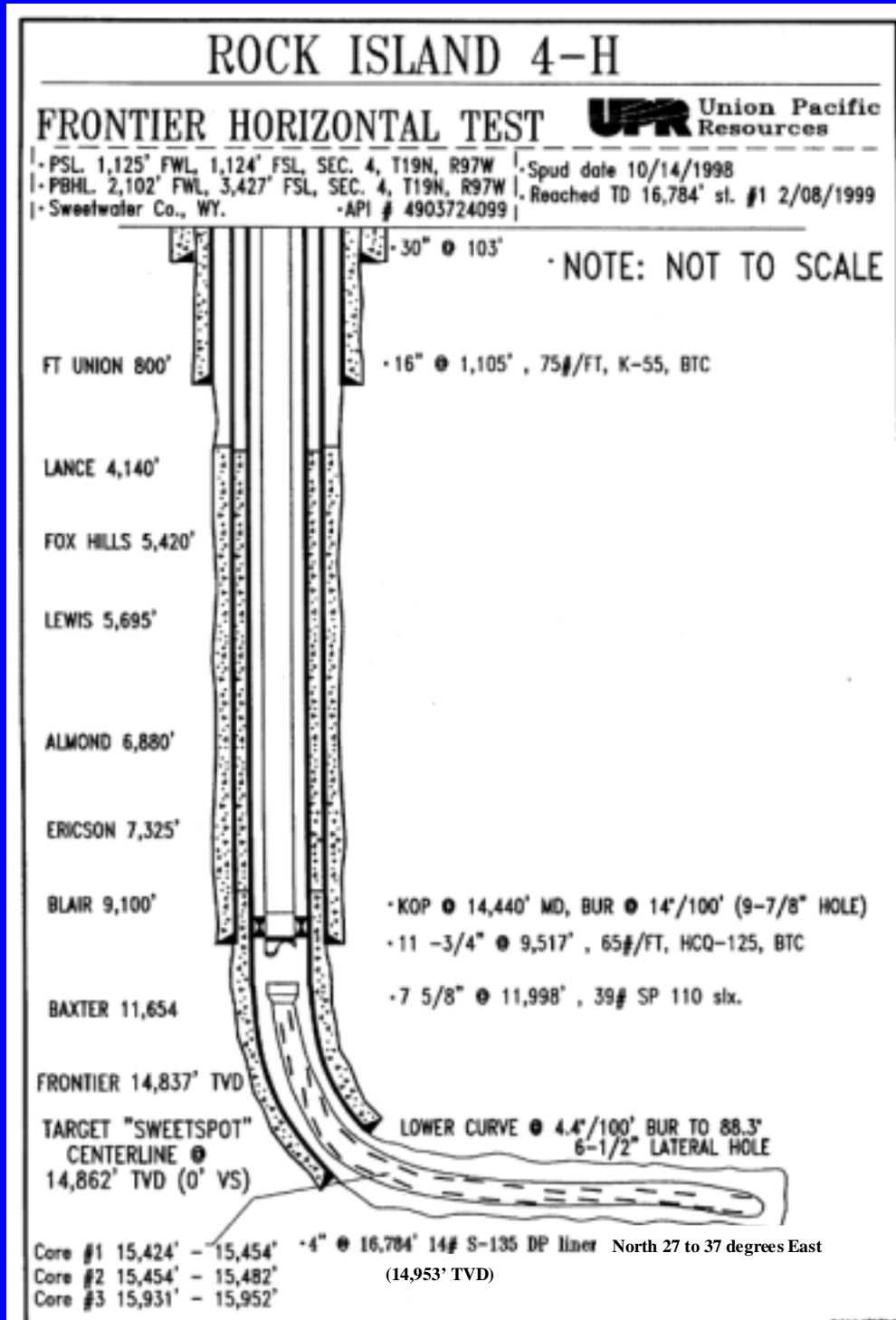
DRILLING DEPTH and COSTS vs. TIME

ROCK ISLAND 4-H - TOTALS to 2/25/99 REPORT (135 Days @ 16,784' & \$5,586,000)

Estimated
Cost



Wellbore Diagram



Chronological History of RI 4-H

Below is a Detailed Time Line of the Complete Well History:

10/14/98 to 11/22/98 Spud, Drill 14-3/4" Vertical to 9,517', Run 11-3/4" Casing

11/23/98 to 12/15/98 Drill 10-5/8" Vertical to 14,440' KOP (Kick Off Point)

12/16/98 to 01/08/99 Build 10-5/8" Curve to 15,025', Run 7-5/8" Liner

01/09/99 to 02/11/99 Drill 6-1/2" Horizontal Lateral to 16,784' (Core and Log)

02/12/99 to 02/24/99 Run 7-5/8" Tie-back Liner from 8,217' to Surface

Run 4" Perforated Liner in Lateral from 14,510' to 16,784'

Run 2-7/8" Tubing to 14,490' with packer set at 14,446'

**02/25/99 Flow Well to Pit 6 hours for Initial Wellbore Cleanup,
(100' Flare at 11/64 choke and 5600psi FTP)**

**03/02/99 to 03/09/99 Flow Well through Separator Test Metering Equipment,
(Rates Measured up to 12 MMCFD)**

**03/13/99 to 03/14/99 Run 4-Point Conventional Flow Test 6, 8, 10, & 12 MMCFD
(26 MMCF Cumulative Gas Produced 3/6/99 to 3/14/99)**

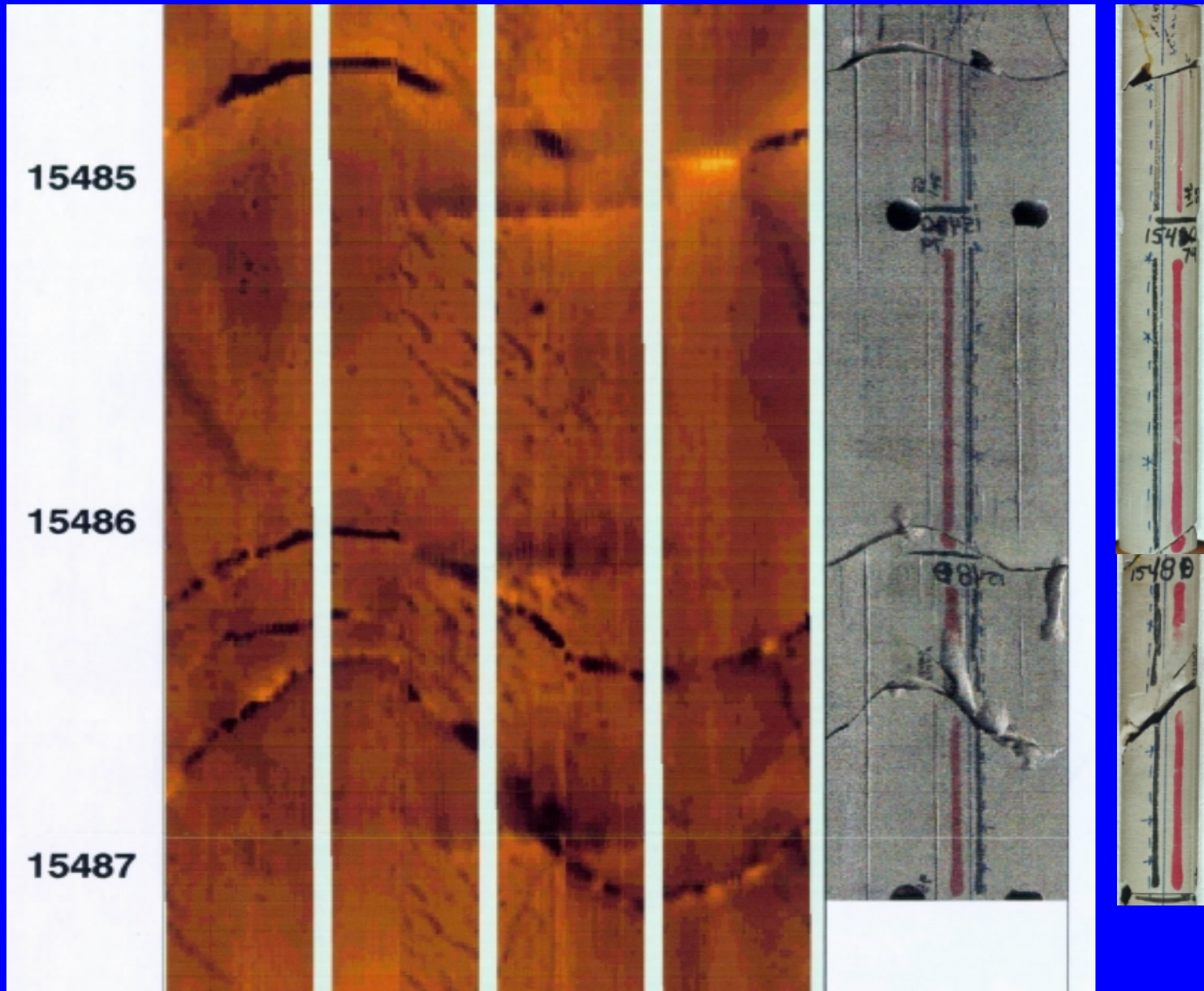
03/14/99 to 03/25/99 Run Shut-in, Bottomhole Pressure Build-up (9,650psi BHP)

03/26/99 to 05/12/99 Well Shut-in Waiting on Pipeline Connection

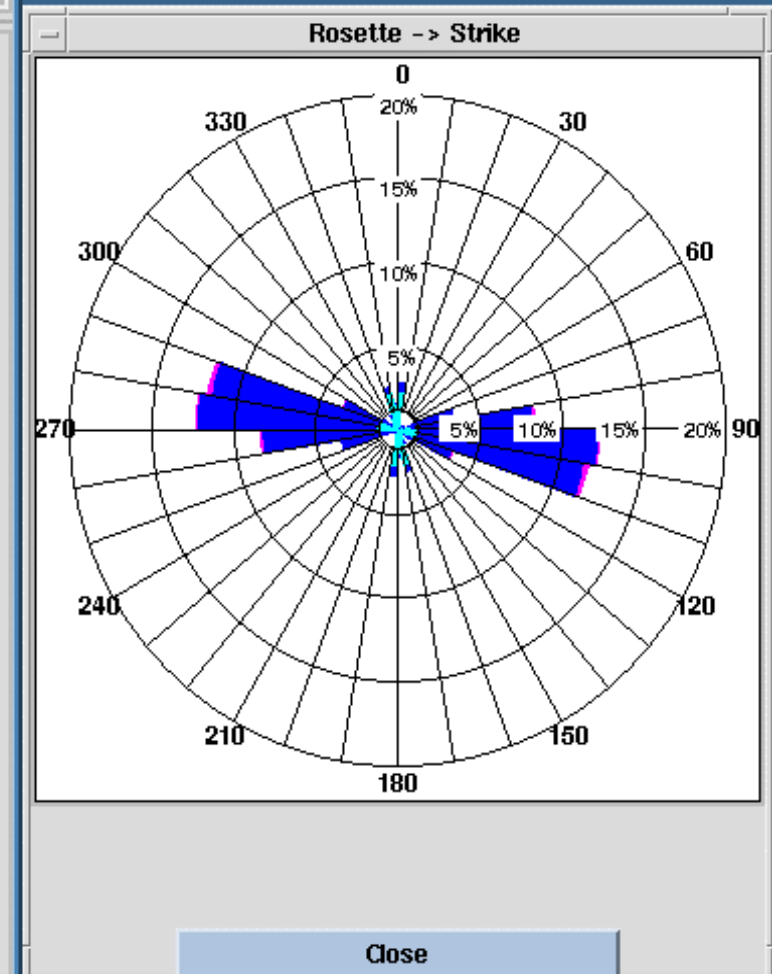
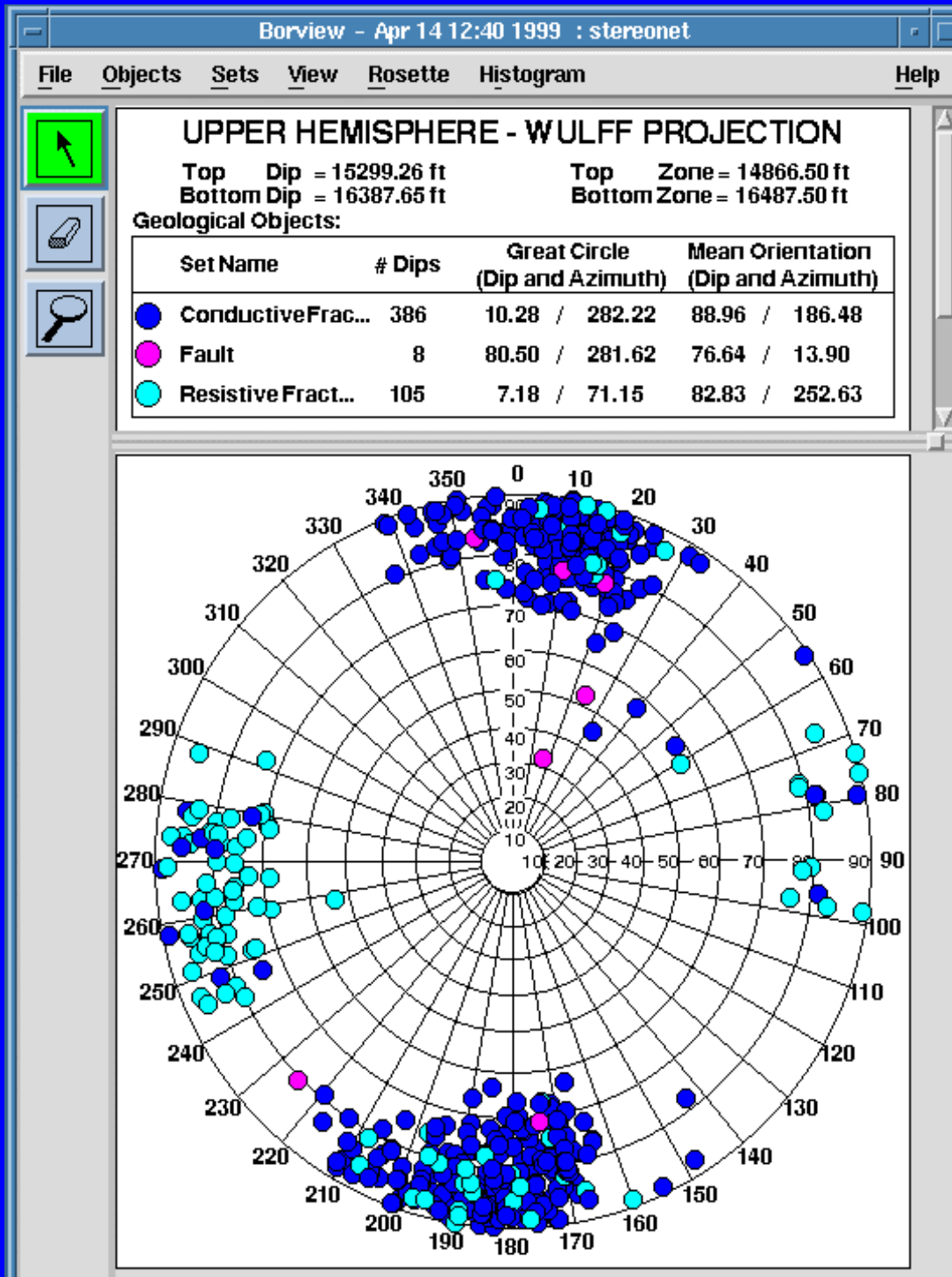
05/13/99 Well Open to Gas Sales at 12 MMCFD Initial Rate

FMI (Formation Micro-Imaging)
LOG USED TO
CHARACTERIZE FAULT AND
NATURAL FRACTURE DATA

Horizontal FMI and Core Comparisons Show Good Correlation of Natural Fractures



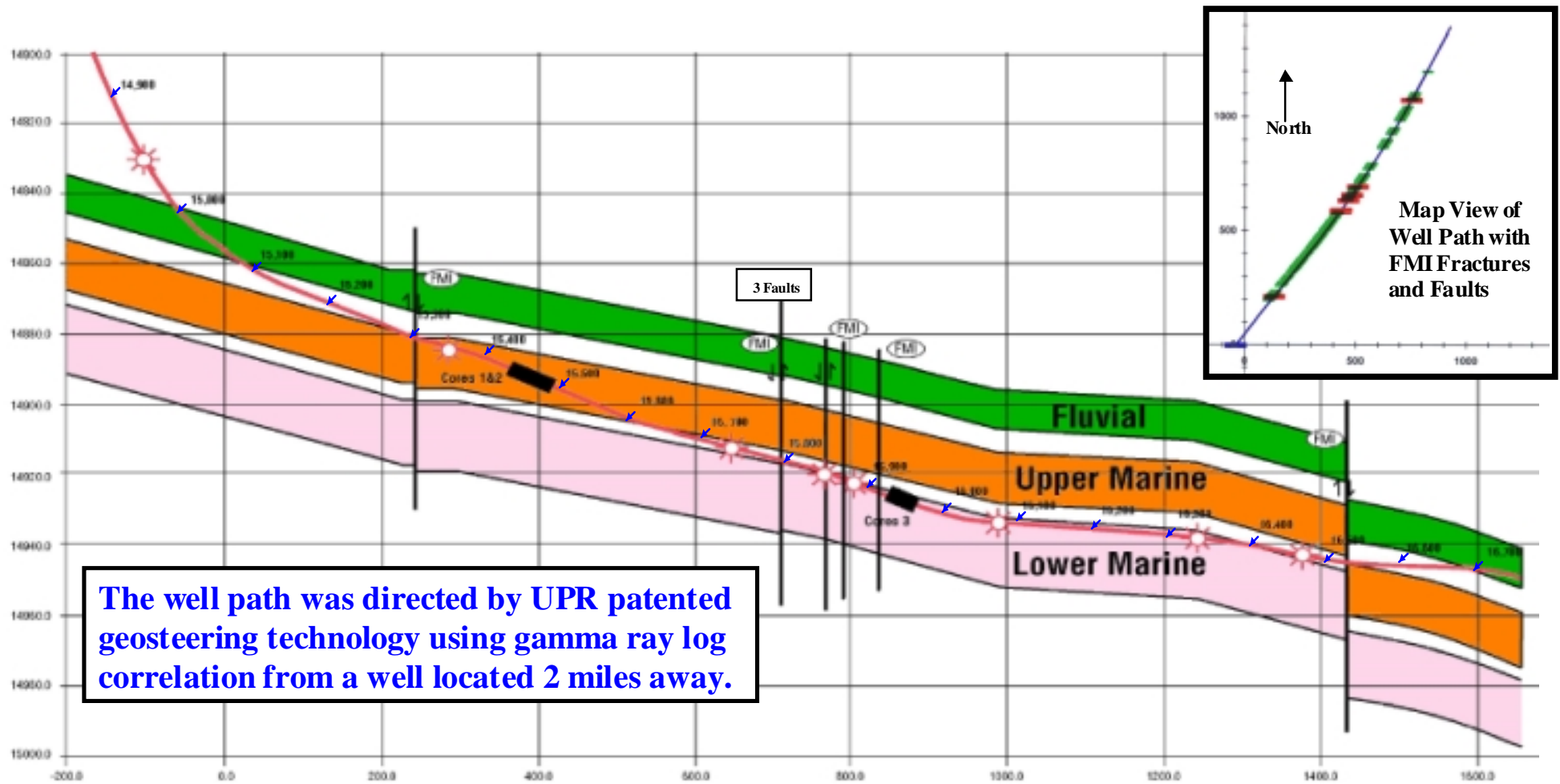
FMI Stereonet and Rose Diagrams



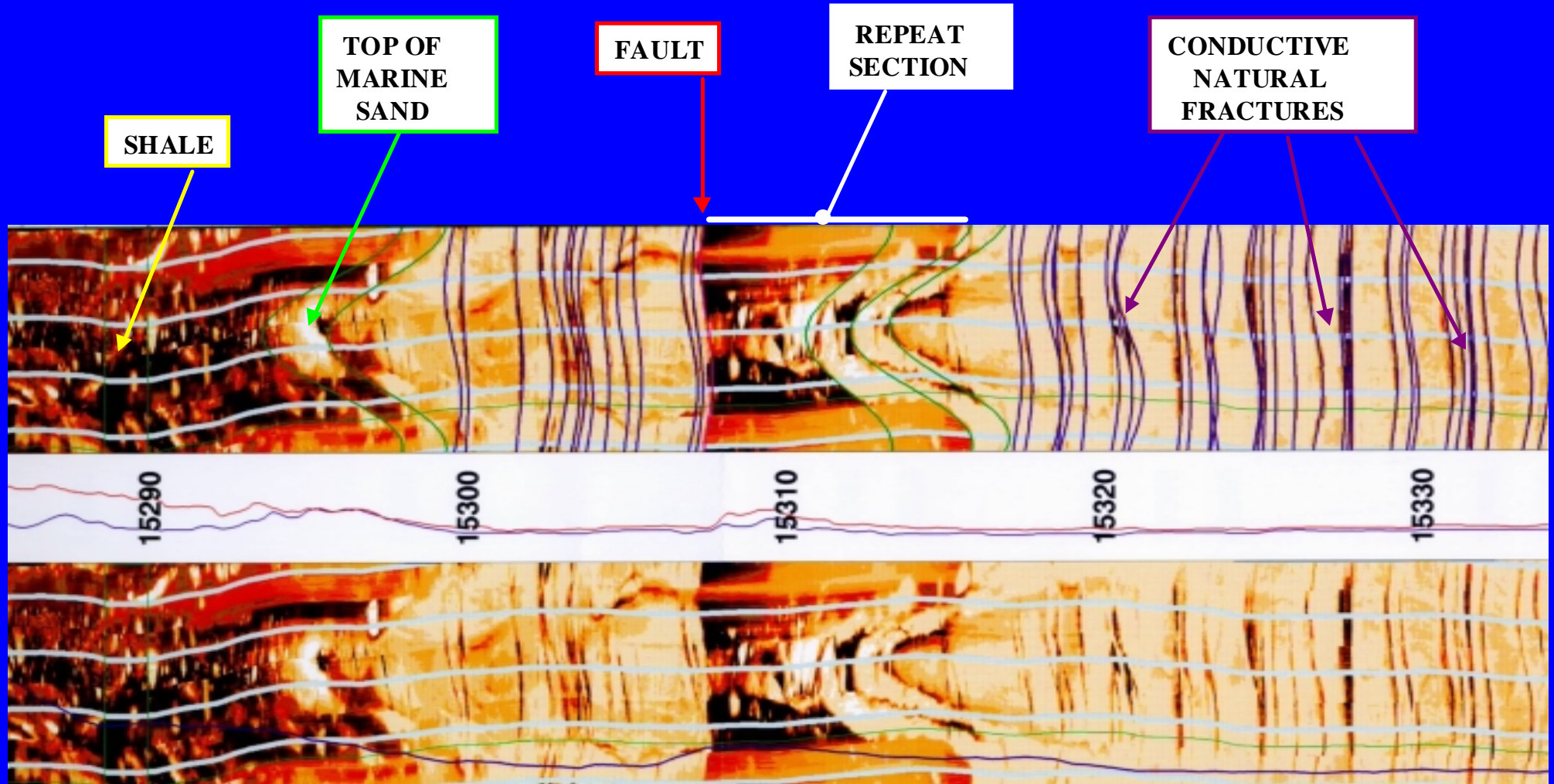
RI 4-H Geosteering Results of Horizontal Lateral

(Post-Drilling, Integrated Geologic Interpretations using FMI and Drilling Data with UPR Geosteering Process)

(Used in April 26, 1999 GRI Presentation in Denver with Updates 5/4/99 for Corrections)

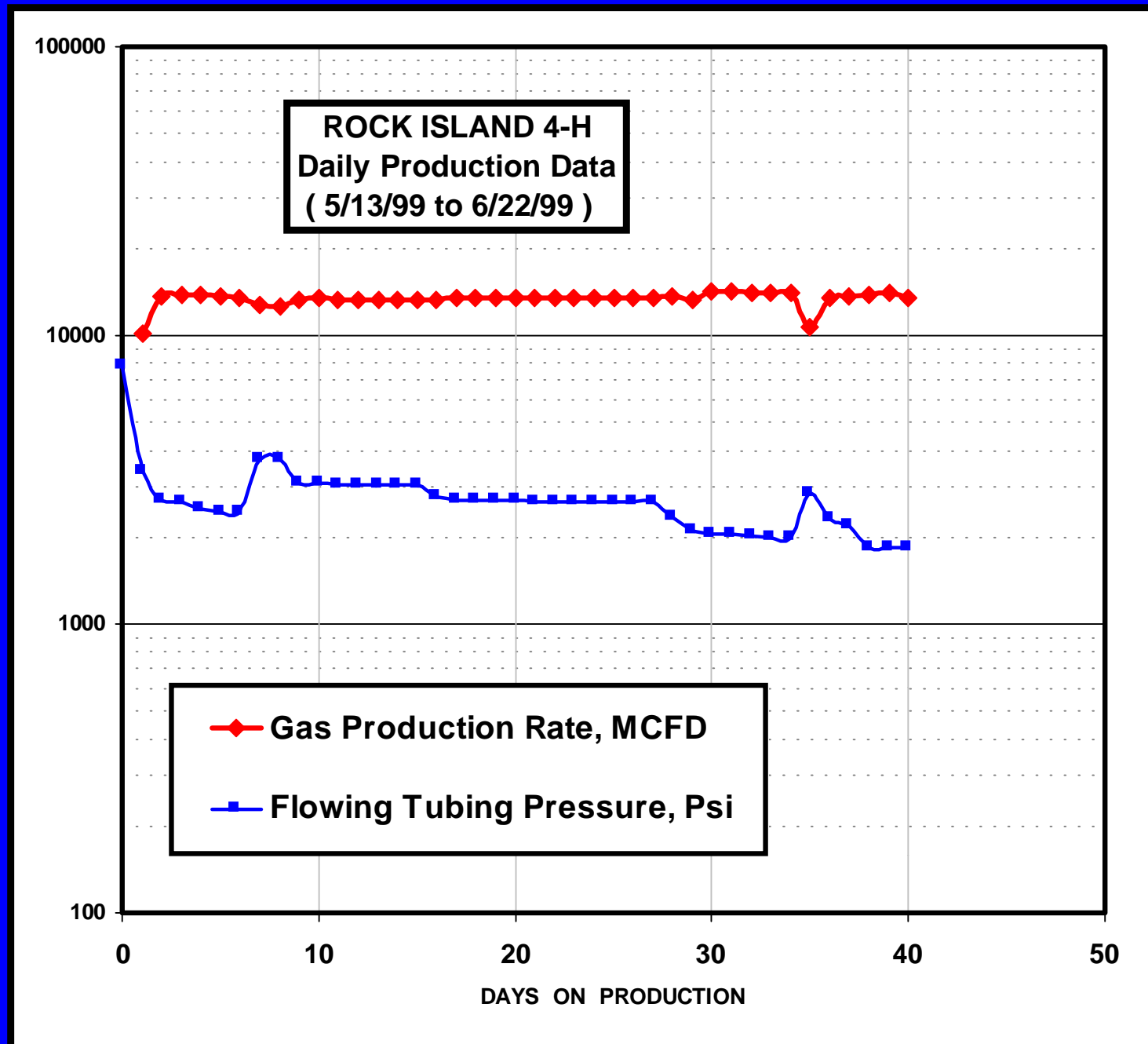


FMI Log of 15,290'-15,330' Horizontal Section



SUMMARY OF PROJECT RESULTS
TO DATE

ROCK ISLAND 4-H PRODUCTION DATA



SUCCESSFULLY DRILLED 1,750' HORIZONTAL LATERAL

(14,973' TVD in FRONTIER MARINE TARGET SAND)

FMI LOG IDENTIFIED GOOD FRACTURE SYSTEM

(386 CONDUCTIVE FRACTURES and 8 FAULTS)

GOOD MATRIX PROPERTIES from LOGS and CORES

(10% POROSITY and 0.025 MD PERMEABILITY)

GOOD PRODUCTION RESULTS from NATURAL COMPLETION

(AVG 14 MMCFD RATE after 40 DAYS PRODUCTION)

*** ADDITIONAL HORIZONTAL WELLS PLANNED by
NUMEROUS PARTICIPANTS to DEVELOP and EXTEND
the PLAY THROUGHOUT the GREEN RIVER BASIN**